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AN ANALYSIS OF SELECTED QUANTITATIVE METHODS TO
AIR FORCE COMMUNICATIONS COMMAND ELECTRONICS
INSTALLATION WORKLOAD ASSIGNMENT AND SCHEDULING

Captain Raymond J. Brylski, USAF
Captain Louise M. Nelson, USAF

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This thesis reviews and evaluates two models developed ~~by Captain Scott A. Hammell~~ to assign and schedule workload assigned to the Air Force Communications Command Engineering and Installations Activities. Each model applies mission and unit unique characteristics of manpower, travel, and personnel skills to develop optimum assignment and scheduling packages. Critiques of the Hammell models and recommendations for their improvement and the improvement of their supporting data bases were made. The thesis concluded that while Captain Hammell's models were basically sound and workable, further development and strengthening of each model may be accomplished by the inclusion of more real world data, clarification of certain assumptions, and construction of a new data base.

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AN ANALYSIS OF SELECTED QUANTITATIVE METHODS TO AIR FORCE COMMUNICATIONS COMMAND ELECTRONICS INSTALLATION WORKLOAD ASSIGNMENT AND SCHEDULING

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

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Captain, USAF

Louise M. Nelson, BA
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June 1981

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This thesis, written by

Captain Raymond J. Brylski

and

Captain Louise M. Nelson

has been accepted by the undersigned on behalf of the Faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

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COMMITTEE CHAIRMAN

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CHAPTER I

OVERVIEW

Introduction

In July 1970, under the Air Force's concept of a single manager for communications services, the Ground Electronics Engineering and Installations Agency (GEEIA) was aligned under the Air Force Communications Service (AFCS), predecessor of the Air Force Communications Command (AFCC). As a result of that decision, AFCC is presently tasked with the annual accomplishment of more than twenty-five hundred installations, modifications, and removals of ground Communications-Electronics (C-E) equipment and systems at Air Force and allied installations throughout the world. To accomplish this workload there are presently eight electronics installation (EI) activities located in the Continental United States, one in the European Theater, and one in the Pacific Theater.

Currently the assignment of the tasks of installation, modification, or removal of C-E equipment is made to installations units on a regional basis; each overseas unit is responsible for the task locations within its geographical region; and the workload for the CONUS is assigned to one of two intermediate headquarters established by a North/South division of the United States. Figure 1.1 shows the present structure of the Communications Command. The operations and maintenance (O&M) function is assigned to the tenant communications unit of an Air Force installation.

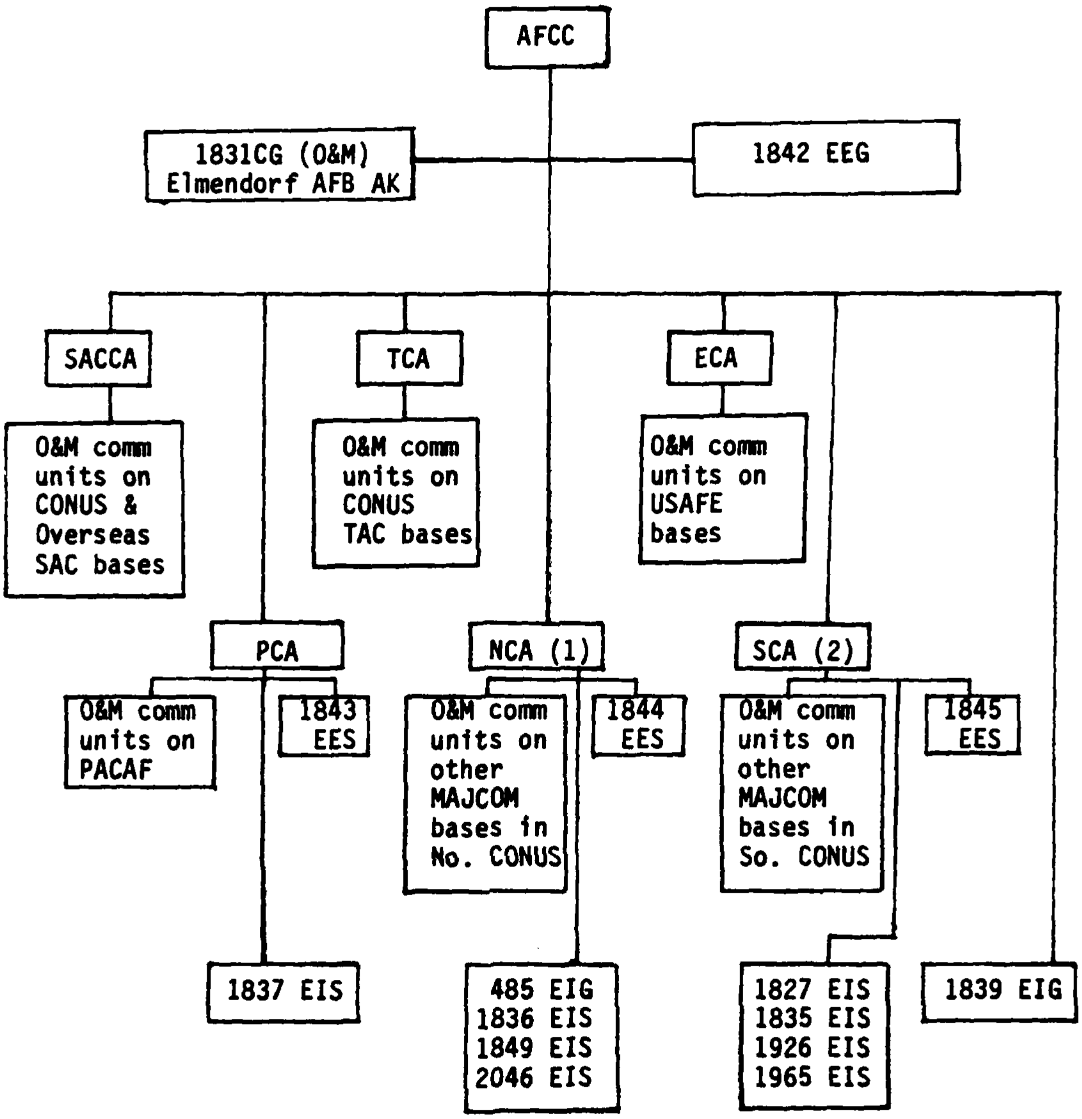

Figure 1.1

AFCC Present Organization

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(1) NCA regional responsibilities include Canada, Greenland, Iceland, the Azores, Grand Bahama Islands, and Eastern Test Range locations.

(2) SCA regional responsibilities include Alaska (E-I only) and the Canal Zone.

The communications unit reports directly to the area command headquarters under which it falls geographically or by host base command; for example, the communications organization at Barksdale AFB, Louisianna, reports to the Strategic Communications Area (SACCA) even though it is in the southern part of the United States, while the communications unit at Kelly AFB, Texas, an Air Force Logistic Command base, reports directly to the Southern Communications Area (SCA). O&M units are responsible for the operations of a base's air traffic control services, telephone and message handling facilities, plus the maintenance of these communications systems and equipment.

AFCC Reorganization

AFCC recently submitted and received approval for an organizational structure change from Headquarters, Air Force (8). Of the changes included under this proposal, the most significant for the purposes of this paper, is the realignment of the entire EI management structure within the command.

Currently the management of the EI mission for AFCC is split among three of the six communications areas. The Northern, Southern, and Pacific Communications Areas (NCA, SCA, and PCA) are responsible for the management of the EI mission within their geographical area. In addition, NCA has engineering and installations management responsibilities for the entire European Theater, and SCA has the responsibility for the management of the engineering and installations missions within Alaska and the Canal Zone.

The new EI structure will consolidate all engineering and installations management at a centralized location under the Engineering and Installations Center (EIC) presently being organized at Oklahoma City Air Force Station. Figure 1.2 shows this new organizational structure.

Other changes, as indicated by Figure 1.2, include: intermediate-level headquarters name changes from Communications Areas to Communications Divisions; the realignment of all CONUS units not assigned to a base hosted by a unified command under the newly created Continental Communications Division; and the creation of the Airlift Communications Division. The latter change supports MAC in much the same manner in which SAC and TAC are presently supported by SACCA and TACCA. The O&M mission remains decentralized under each new division. This realignment presents both interesting challenges for the management of the EI mission and also several opportunities to utilize quantitative assignment and scheduling models for the distribution of the EI workload among the command's installations capable units.

Justification

This thesis is a follow-on effort to two previous works accomplished in 1979 and 1980. Nauseef, et. al, (12), approached the topic of, "The Identification of Performance Factors for the Engineering and Installation of Ground CEM Systems." Their paper examined the goals and objectives of the Command in the engineering and installation of Communications-Electronics-Meteorological (CEM) systems. Among their recommendations was the formulation of quantitative methods to enhance the area of EI workloading. Captain Hammell, in 1980, did that in a thesis

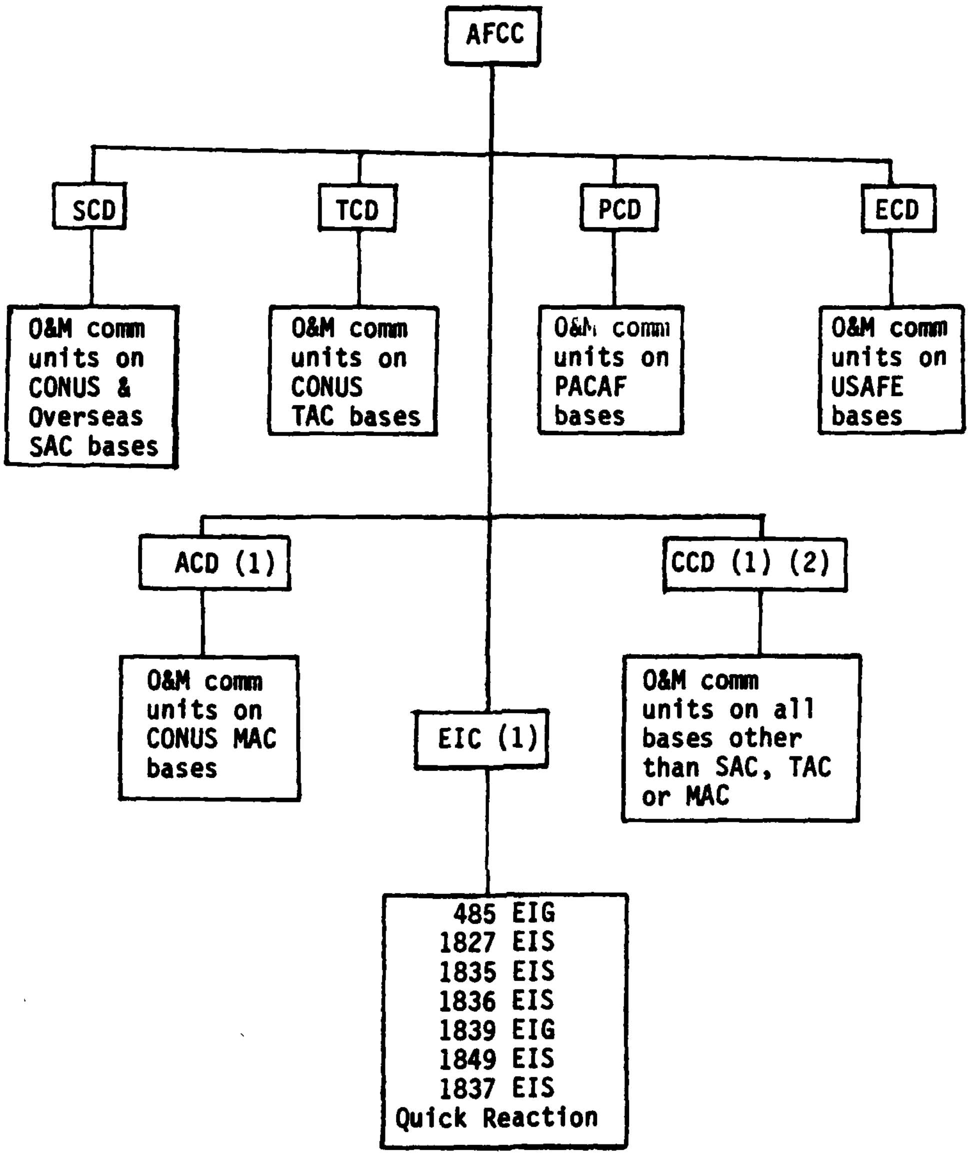

Figure 1.2

AFCC Reorganization Plan

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(1) Newly created intermediate headquarters.

(2) The Continental Communications Division assumes responsibility for O&M organizations formerly under NCA and SCA plus responsibility for the Alaskan units which reported directly to Headquarters AFCC.

entitled, "An Approach to Workload Assignment and Scheduling of Engineering and Installations Activities for Air Force Communications Command" (10). Captain Hammell proposed, developed and verified management science methods to assign and then schedule EI workload to AFCC EI activities. The models will work using hypothetical situations, however according to Hammell, "It is necessary to expand this effort to incorporate some real world aspects in the models which had to be assumed away [10:90]." The models must now be validated to bring to an acceptable level the user's confidence that pertinent components of the EI workload assignment and scheduling activities have been included in each model.

Review of an Air Force Communications Service Project Proposal titled, "AFCS TAB 35123--EIMS Software," which proposed the further expansion and updating the EI Management System (EIMS), revealed that the Command has four specific requirements which will allow the system to provide enhanced capability for the accurate, long-range commitment of implementation resources [3:2]. These are the development of:

a. Workload Assignment System: to evaluate implementation requirements versus resource availability, remove the geographical boundaries for the division of work, provide consideration for seasonal work, and allow task leveling among the EI units.

b. Automated Standards Updating and Estimation System: to compute and keep current standard engineering and installations manhours for use in project estimation.

c. Milestone Adjustment System: an automatic system to order programs, offer alternative courses of action, and maintain cognizance of all interested parties when changes occur.

d. Unapproved/Forecasted Workload Projection System: to allow identification, estimation of costs, and estimation of man-hours required for all potential EI workload for up to a seven-year period.

The Communications Command has validated these requirements. This thesis will focus its attention on evaluating Hammel's models and defining requirements for a working model in support of the first subsystem requirement of the AFCS TAB.

Lieutenant Colonel Joseph T. Stewart, Deputy Chief of Staff for Engineering and Installations, Northern Communications Area, indicated that the command is still vitally interested in the development of the EIMS, with the development of software in support of the Workload Assignment System of prime interest (15). The desired completion date for this system is 1983.

Problem Statement

The problem addressed by this research is to analyze these quantitative models for EI workload assignment and scheduling, to appraise each model's relevant points, and to discuss what aspects of EI workload must be considered for an effective and workable assignment/schedule model.

Research Questions

The overall objective of this research effort was to more closely define what EI workload assignment/schedule models must consider. To achieve this objective, the following research questions should be answered.

1. Is it possible to develop models to effectively assign and schedule EI workload?

2. What are the major objectives of such assignment/schedule models?

3. What factors must be considered in these models?

4. How can EIMS be used with these models?

CHAPTER II

LITERATURE REVIEW

Although improvement of the method of assigning workload to the various electronics installation activities throughout the United States, Europe, and the Pacific has been a desire of the AFCC Engineering and Installations managers throughout the years, it has only been recently that the problem has been addressed. Work on this thesis began with a review of the literature related to AFCC workload management, Captain Hammell's models developed for EI workload assignment and scheduling, and the data base used in EI management.

AFCC Workloading Concept

AFCC's Concept of EI workloading [8:2], as presented to the command's Plans Office by the Directorate of Engineering Programs, is the command's proposal for EI workloading when the proposed Engineering Installations Center becomes operational. In the area of workloading, the objectives of the command are to: minimize travel mileage as a means of reducing travel costs; uniformly work the various skills assigned to the command's EI activities, regardless of the activity owning the skills; and to work these skills geographically, according to a seasonal schedule, which allows scheduling in a North - South manner in accordance with seasonal changes in the weather.

Within the paper on the Concept of EI Workloading, the command also addressed the need to assign workload by priority to insure that the possibility of accomplishing low priority work while leaving higher priority work unfinished is unlikely. Thus the scheduling of the workload becomes critical to both workload management and workload assignment.

The Hammell Method

Captain Hammell's 1980 thesis proposed the use of two mathematical models for the assignment and scheduling of the EI workload. His proposal resulted in a two-step process. The first step assigned workload to EI activities by the use of a linear program which minimizes the one-way travel mileage. The single driving variable for the assignment model is the distance between the job location and the alternative choices of EI units for assignment to that job. The next step involves scheduling the workload at each particular unit through the use of another linear program. In the scheduling model, the driving variables are resource availability and the requirement for concurrency, sequencing, or non-concurrency of assigned jobs. Workload leveling in the scheduling model is the attempt to equally spread the EI workload throughout the available EI units.

Engineering Installations Management System

Captain Hammell used data obtained from the Engineering Installation Management System (EIMS), an information management system, to verify his assignment and scheduling models. A review of this system (1) provided insight on its operation and construction. The data base,

comprised of 182 data fields in 801 positions, contained information used by all the people concerned with a C-E scheme, from the Air Force site where the job will be done, to the EI unit scheduled to do the jobs, and finally to the engineer and the programmer at area headquarters who engineer and monitor the job progress. The review of the data base was necessary to understand the algorithms and the manipulation of data used by Hammell.

Summary

This chapter has presented a review of three basic areas: AFCC concepts of EI Workloading; Captain Hammell's proposed use of Management Science to deal with specific areas identified in the AFCC Concept Paper; and the area of EIMS which will be the instrument this thesis will use to test and evaluate the Hammell method of EI Workloading. An understanding of the EIMS system is required in order to further incorporate the system into the algorithms of Captain Hammell, should they prove to be satisfactory.

CHAPTER III

VALIDATION REQUIREMENTS

Since the assumption of ground electronics, engineering, and installations functions by Air Force Communications Command (previously Air Force Communications Service) in 1970, AFCC has sought to enhance the method of assigning and scheduling the workload of engineering and installing ground C-E equipment and systems. As discussed in Chapter I, the command is still vitally interested in the development of the EI Management System (EIMS), especially the workload assignment system component.

In 1980, Captain Hammell described quantitative methods for the assignment of installation workload to AFCC EI activities and for the scheduling of these missions at the unit level to facilitate their accomplishment. The Hammell method was developed and verified first using simple contrived simulations and then a limited number of actual jobs to determine the workability of the method. These models were shown to be capable of both assigning and scheduling EI workload. In addition, the models met certain command criteria of lowering travel costs, leveling resource utilization, and further, providing a systematic method for assigning workload using proven management science techniques.

This chapter describes the variables used in the Hammell models and how the input for the models is set up. Captain Hammell was able to

extract most of the required data from the EIMS data base. This data was manipulated to fit into the models' format. Other data bits were manually calculated for input into the models. The chapter also discusses why validation of the models was not accomplished at this time.

Variables

The Hammell method utilizes a total of eight variables for the accomplishment of the assignment and scheduling allocations. The EIMS data base is used to provide values for six of these variables, which include: (1) the location of the job, (2) a work identification number, (3) total manhours required to complete the job, (4) the estimated start date (ESD), (5) the estimated completion or due date (DUE), and (6) the skills and number of persons per skill to complete the job. Values for each of these variables are determined by translation of the EIMS data field records. The EIMS data is accessed through the command's Honeywell 6600 computer system. This data includes all jobs assigned to the Northern and Southern Communications Areas (NCA & SCA).

Further variables required for the models are obtained or calculated using means other than direct translation of EIMS data. The seventh variable, called mileset, comes from the distance matrix made up of the distances between the various job sites and the EI units. This matrix is constructed using the Official Table of Distances, AFR 177-135 (17). However, when a location is not listed, estimates can be made using map distances and the listing for the next closest location.

The eighth variable required as input for the models is duration of a job in days. The estimated start and completion dates (ESD & DUE) are converted into Julian dates. To obtain the duration time, the start date is subtracted from the completion date. An example follows: a job's ESD is 12 October 1980 with a DUE of 19 February 1981. 12 October 1980 is changed to the Julian date of 286. In converting the DUE, the year must be considered. If the year of the DUE is not the same as that of the ESD, the number of days in the ESD year must be added to the DUE actual Julian date. For 19 February 1981 (Julian date 50), 366 (days in 1980) is added to 50 for a Julian date of 416. Thus, the duration is 130 days (416 - 286).

Additional data the user must manually input into the models are: (1) EI unit identifier, (2) skill availability, (3) manpower availability, and (4) manhours available per unit for the test period.

Computer Programs

The assignment and scheduling models are each comprised of two computer programs. The output for the first program becomes the input for the second. This two-step process is basically a reformatting of the eight variables mentioned above for accomplishment of two linear program problems. To help the reader comprehend the Hammell method, the assignment model programs will be discussed.

Captain Hammell's first step in the assignment of jobs is the utilization of a FORTRAN program. This program considers those variables which most affect the stated objectives: minimizing travel costs and

leveling resource utilization. These variables are manipulated and rearranged to obtain the correct data format for the second program. This program uses a linear programming (LP) system available on the Honeywell 6000 series computers. The LP6000 system consists of mathematical algorithms which can perform a variety of LP functions. For the assignment model, it accomplishes a modified transportation problem (10:46). The output for this model resembles a type of matrix, with row entries representing jobs and column entries representing EI units. The EI unit which is assigned a certain job is designated by a one (1) in the column of that unit.

Validation

When the authors' explored the feasibility of further testing the Hammell method, they experienced several problems with the data base and the factors considered by the models. It was felt that EI workload information for one fiscal year quarter from EIMS would serve as a more than adequate data base upon which to test the models. A listing of all NCA and SCA jobs was obtained. This listing for first quarter fiscal year 1981 (1FY81) consisted of 488 jobs assigned to all NCA and SCA units. However, 133 of the 488 jobs were promptly eliminated because these jobs are for European bases. The European EI workload is primarily handled by the 1836 EIS, Lindsey AFS, Germany. Thus, it was not practical to include these jobs. This factor left the authors with 355 EI jobs in the Continental United States, Alaska, and the Canal Zone. The Alaskan and Canal Zone workload was also excluded as mileage figures for the distance matrix were

extremely difficult to estimate. This reduction then left the authors with a total of 338 jobs, or 69 percent of the 1FY81 workload to be used in testing the models. But the EIMS data base, like others, is only good as long as it is updated and maintained. After additional screening of the listing, it was discovered that only 196 of the remaining 338 jobs contained all the required variables. Thus only 40 percent of the total EI workload for 1FY81 was usable for testing of the Hammell models. This quantity of EI workload was further reduced by restrictions to Captain Hammell's assignment model. He found it difficult "for the computer to reach an optimum solution within reasonable limits of core memory and computational time [10:78]." Consequently, the assignment model only considered 150 jobs at one time. For one run of the computer program, 30 percent of the 1FY81 workload would be assigned. This factor also affects the available manhour figures used in the assignment model. These figures would need to be adjusted appropriately each time the computer program is run, so the amount of manhours considered for each unit correctly reflects hours available for the number of jobs considered.

A validation of the scheduling model would not provide any relevant findings at this time. Unlike the assignment of EI workload, there is no listing of how a unit's jobs were scheduled through the quarter. Thus, no comparisons could be made between the validation test results and an actual schedule of workload.

The next chapters more fully evaluate the Hammell method and recommend improvement areas. They discuss what aspects of EI workload assignment and scheduling need to be incorporated into the models. For

these reasons, proper validation of the Hammell models would not be productive at this time. Once the authors' recommendations are incorporated into the models and the EIMS data base is "cleaned up", validation should be attempted.

Validation Methodology

When recommended improvements have been made to the Hammell models and problems with the EIMS data base are corrected, the following methodology can be followed for future validation efforts. It is, of course, assumed that the present AFCC method for assigning and scheduling workload is an effective and relatively efficient method and will be continued by program managers at the new Engineering and Installation Center (EIC).

For validation of the assignment model, a comparison of actual job assignments should be considered. The assignments made by the model would be compared on a job by job basis to those assignments made by AFCC during the time period being tested. Those assignments which do not correspond with those made by the command will be totaled. The total should then be compared to an alpha risk of a certain percentage--such as five percent--of the total number of jobs assigned to determine the overall effectiveness of Hammell's assignment model.

A five percent alpha risk would mean that five out of one hundred jobs assigned by the Hammell method were assigned to units other than the units actually tasked with mission responsibility by the command. Those allocations which are different than the real world assignments should then be reviewed to determine whether Hammell's assignment model allocated resources to jobs in a more efficient manner using system objectives as measurement factors.

As mentioned before, there is no actual schedule of EI workload for a unit as there is an assignment listing. Therefore, no comparison is possible. To validate the scheduling model, the schedule produced should be carefully reviewed for continuity, maximum utilization of resources and compliance with command quality of life policies concerning maximum manpower utilization.

<u>Summary</u>

This chapter has elaborated on what variables are required to test Hammell's models at this time. The necessary calculations and researching of these variables was discussed. The authors did not attempt to validate the Hammell method because of problems with the EIMS data base and with important factors not included in the models. The next chapters discuss what these factors should be. A methodology for future validation efforts was covered. This methodology cannot be attempted until the authors' recommendations are incorporated and the EIMS data base is properly updated and maintained.

CHAPTER IV

EVALUATION OF THE HAMMELL METHOD

This chapter presents an expanded discussion of the Hammell Method of EI workload management. The assumptions, data base requirements, and decision variables are specifically addressed. The chapter includes the authors' evaluation and critique of the two models used by Captain Hammell.

Problem Definition

Captain Hammell did extensive background studies in order to research the EI workload management problem, to ascertain the need for a new decision support system, and to determine the function of the Directorate of Engineering and Installations at AFCC headquarters and its lower echelon counterparts at Area headquarters. As part of his research he proposed and answered the following questions:

1. What is the nature of the Engineering Installations workload assignment and scheduling problem?

2. What is the desired relationship between the job assignments and level of EI unit tasking?

3. Can an automated system be established which will identify optimum start dates within a set of certain criteria?

4. What is the relationship between the level of utilization of available EI resources and the scheduling of missions to those resources?

Captain Hammell also identified and included in his models the following command policies relating to the employment of EI resources.

1. The command desired that some method be found to level the utilization of particular resources across the seven EI units.

2. The command desired to minimize the amount of travel performed by an EI unit, primarily to conserve funds.

3. The command required that the Required Operational Date (ROD) set by the requesting organization, be met within the constraints imposed by time, money, and personnel.

4. The command policy of team integrity; the concept which requires that all team members come from the same unit, was to apply in all but exceptional cases.

As a result of answering his research questions, and in order to meet the policies and desires of the command, Captain Hammell developed a decision support system to solve EI workload management problems in the assignment, scheduling, and resource allocation areas.

Within the constraints of the problem, workload assignment was defined as the act of tasking a specific unit with a specific job. Because all team members must come from the same unit, the act was determined to have the same characteristics of the classical assignment problem described by management science theory (6) (14). In relation to the economies of travel, the assignment problem was also determined to be a specialized case of the general transportation problem [10:46] and the classical transportation algorithm was used along with the general assignment theory to determine an optimum assignment of jobs to units.

The scheduling of jobs within the same unit; defined as the act of stipulating when a job or task was to be accomplished, was considered to be the ordering of a collection of jobs in some predetermined fashion (13). The jobs were ordered by using the criteria of required operational dates versus the available direct labor and job manpower requirements to arrive at an optimum schedule.

The leveling of resources throughout the command was satisfied by the allocation of jobs to units to equalize the utilization of personnel within a specific skill area across units and time periods.

Captain Hammell's work is an excellent application of management science and innovative approaches within the area of multi-skill multi-job management. There is potential for model improvement to produce very realistic and valuable decision support systems.

The Data Base

By working with the already existing EIMS data base, the Hammell Method makes use of an available and underused information system familiar to all EI personnel. His models, with several changes and additional features incorporated to account for real world problem areas, provide the opportunity for the Communications Command to more fully utilize EIMS and may be an important factor in some of the design considerations for the follow-on system to EIMS [3:2].

The Hammell Method requires information found in a relatively small number of the 182 possible data files located in the EIMS data base. Using the files of mission location, required skill type, estimated

manpower requirements, installation time, and required operational dates, the user of the Hammell Method may extract and manually reformat the data required by the models. Other required data; distance between the mission location and the alternative EI resources, and the estimated available manhours per skill at each unit, were computed using other readily available resources and input into the data base required for the Hammell Models.

For each run of the assignment model, the user must manually create a distance matrix (Appendix B) using the Table of Official Distances (17), maps, and estimates as described in Chapter III.

Computation of the available direct labor resources is accomplished by using the command's historical average annual manpower availability rate together with the number of direct labor personnel assigned to each unit at the beginning of each planning horizon.

In evaluating the required variables, the authors found that several problems were associated with the EIMS data base, the distance matrix, and direct labor resources data sources:

1. The EIMS data base, while extensive, was usually inaccurate or simply incomplete. Forty-five percent of those missions on the job listing under consideration in this evaluation were deleted due to problems associated with the data found in the EIMS data base.

2. The task of manually changing the data from the EIMS format to the format required by the Hammell algorithms becomes a long and tedious task requiring an extensive amount of time and labor on the part of the program users.

3. By using the Official Table of Distances to determine the distance between the mission locations and the alternative EI Units, the authors again found that an extensive amount of time was spent in what is considered only marginally productive labor.

4. By using the command average direct labor availability rate it was determined that in the short run the figures obtained may be highly inaccurate as several seasonal factors were ignored by the model.

The Hammell Method

The stated purpose of the assignment and scheduling system is to provide concise management information to facilitate the decision making process of certain functions within the AFCC Engineering and Installations Center. Specifically the objectives of the Hammell Method are to:

1. Determine the most cost effective assignment of missions to units by minimizing the travel cost criteria.

2. Optimize the scheduling of assigned missions within each unit to insure the efficient use of manpower within that unit while still meeting certain constraints of resource utilization, maximum mission length, and required operational dates.

3. Insure a command-wide leveling of resource utilization within career fields and across time periods.

The Assignment Model

The specific time horizon used by Captain Hammell was a four month period, however, the algorithm readily allows the time horizon to be changed by the user to account for specific situations. The variables

considered in this model were the location of the job site, skills required to accomplish the mission, the manhours and the required operational date of the installed equipment. By working these mission variables against the resource variables of EI unit location, available skills, and available manpower, the Hammell Method was able to provide an optimum assignment of jobs to units.

During this evaluation, it was found that the unit manpower availability figure, based on the command's average availability rate, was much too inaccurate for the purposes of this model. First, the figures were based on the assigned manpower at a particular unit on the particular date of data collection. Second, the data was then factored by the command's historic availability rate of 64.5 percent. Third, while arguments against the long run accuracy of this availability rate cannot be made; in the short run this figure deviates significantly from real world data. This deviation became increasingly larger as the time horizon became smaller and significantly effected the usefulness of the model as an aid to decision making. Inaccuracies were found to be a combination of the seasonal nature of leave requests, sick calls, extended illnesses, and lost time due to permanent change of station moves. In addition, the lost time due to non-direct labor temporary duty missions, travel time, and compensatory time-off were not considered. The inclusion of this real world data, not available to Captain Hammell, would greatly enhance the value of this model.

Captain Hammell correctly considered the availability of a needed skill type at an EI unit as a mandatory condition for unit job assignment; however, his assignment model does not consider the availability of manpower or direct labor time within that skill as a constraining parameter. The algorithm also does not consider the availability of a skilled team chief for that mission.

The algorithm computed the approximate total available manhours within the unit by summing the number of all direct labor assigned personnel, multiplying this by eight hours per working day, and factoring the resulting total possible manhours by the command's historical direct labor availability rate. This resulted in the appearance of more manpower per skill than was actually available. For example; within unit XYZ there are three different direct labor skills: A, B, and C. Each skill type has five hundred available manhours. By using the data base required by the Hammell assignment method, it is possible for the algorithm to assign fifteen hundred manhours of workload to the A skill personnel within the XYZ unit even though only five hundred manhours are actually available.

Considering the problem of team chief availability, the authors found that there exists the possibility of assigning workload to a unit with too few team chiefs to complete the work. The mission of the EI Team Chief is that of expert technician, experienced installer, job foreman, and representative of the unit commander. As such, the responsibilities and the requirements of experience, maturity, and training are so great that there historically has been a lack of skilled team chiefs.

Even though unit personnel are available, jobs remain unstarted on a day to day basis, because of the shortage of team chiefs to lead the missions. The lack of consideration of this significant variable within the Hammell assignment model will produce sub-optimal results in the assignment of workload to units.

The assignment model uses the mileage between the job locations and the alternative EI units as a measure of the cost variable. Thus, to achieve the goal of cost minimization, the model minimizes travel distances. The assumption made, that least miles always equals least cost, may be debated. Numerous exceptions may be cited; however, one will suffice for the purposes of this discussion. By using airline rate schedules and ground transportation costs, it was determined to be cheaper to transport an EI team to Kansas City, MO, from McClelland AFB, CA than from Griffiss AFB, NY. Yet, by the use of the algorithm, which makes assignments based upon distances, the optimum assignment would task the Griffiss AFB team for the Kansas City requirement if all other factors are equal. Today, especially considering the varing rate structure of airlines under deregulation, the relatively high cost to travel to and from off-line locations, and the increasing price of fuel, strict mileage comparisons may result in sub-optimal solutions in some cases.

The final conceptual problem found in the assignment model was that of determining which jobs had to be accomplished, and which jobs may be slipped when there were conflicts. Of the original 488 jobs examined, for example, 39 or eight percent, were found to have the same 366th Julian Day completion date. This scheduled completion date, known as the required

operational date, is that date set by the requesting command to insure that no mission degradation or follow-on support problems occur due to not having the equipment available. The ROD concept was developed to provide Communications Command with specific mandatory completion dates. However, since ROD is required for each communications program request, many RODs are selected in an arbitary manner with little basis of actual need. Since there are numerous cases where the RODs for different priority jobs fall on the same date, and since the Hammell algorithm considers jobs on a case by case basis, there is a high probability that the assignment algorithm will schedule a low priority job before a high priority job. For example, in the case where jobs at Andrews AFB and at Barksdale AFB are assigned to the same unit, and where the data is entered in alphabetical order, all jobs at Andrews will be scheduled before any jobs at Barksdale, when the RODs are the same. This is true even though Barksdale's jobs are of higher priority.

In addition to the conceptual problems discussed above, there is an operational problem in using the assignment model as a flexible decision support system. It was discovered that changing the number of jobs to be considered, the manpower required for a particular mission, skill area needed, and required operational date was easily accomplished since these are input parameters for the assignment model. However, the resource variables cannot be easily changed since these are part of the computer program rather than treated as input parameters. That is, in order to change the model to reflect resources available within EI units or total

manhours available, the program user must manipulate the assignment algorithm program. The extensive work required to modify the program to include real world factors or desired experimental conditions becomes very time consuming and limits the assignment model as a management tool.

The Scheduling Model

Captain Hammell's workload scheduling model not only provides an excellent application of management science techniques in setting schedules for a multi-skill unit, it also holds promise of satisfying the goal of the development of a milestone adjustment system as described by AFCS TAB 35123.

The Hammell Model focuses on the minimization of job throughput time, within certain constraints, as the desired method of efficiently scheduling workload at a particular unit. The constraints considered by the model include the available manpower, required operational date, and the command's desired skill utilization level. The data for this model is once again either taken from the EIMS data base or obtained from the unit and manually processed into a suitable format.

The primary influences on this model are the resource requirements of the job and the manhours which are available within the unit. The user of the model may quickly perform a sensitivity analysis of the changes of certain factors by manipulation of the desired level of skill tasking, mission requirements, or skill availability. For this purpose alone, the model can serve as a valuable tool and become an integral part of a decision support system for AFCC programmers, personnel managers, and commanders.

The model properly develops an optimum feasible schedule and provides information for the construction of graphic resource utilization models to depict skill utilization across units, skill areas, and time periods. The model allows the forced scheduling of certain jobs at particular times, which enables the immediate and ripple effects of that decision to be studied over a number of future time periods. The same method of forcing particular jobs into work will force the program to construct alternate optimum schedules which can serve as a valuable tool to aid in the scheduling of leave, training periods, or other variable non-direct labor activities.

Within the scheduling model, as within the assignment model, the EI Team Chief availability is not considered, thus allowing the possibility of assignment of jobs for periods when there is no team chief available.

A second criticism already discussed under the assignment model, that of lack of consideration of mission priority, is also a factor in the scheduling model.

Summary

As has been shown, excellent work has been accomplished by Captain Hammell in the development of the Assignment and Scheduling Models. Both models have been instrumental in demonstrating that quantitative methods are appropriate for the effective and efficient assignment and scheduling

of multiskill workload. Within the area of programming for the installation of Communications, Electronics, and Meteorological equipment, several improvements may be made to produce better models.

The next chapter discusses recommendations for changes to the Hammell models.

CHAPTER V

RECOMMENDATIONS FOR IMPROVEMENT

As discussed in Chapter IV, Captain Hammell's models for workload assignment and scheduling provide an excellent example of the application of quantitative methods for assigning missions to AFCC Electronics Installations Units. Further development of the Hammell models to include; incorporation of real world data characteristics, program modification to allow more generalized use, and changing some assumptions used to justify the processes by which the models assign and schedule workload, will vastly improve the final program product. An increase in the efficiency by which the user can deal with the Hammell Method will also be accomplished by these model changes. In this chapter the authors describe recommended changes to each model and to the data base, and discuss how each change enhances the usefulness of the model.

Data Base

Captain Hammell's innovative use of the extensive data base of the Engineering Installations Management System is an excellent example of utilization of a management information system which is familiar to all EI personnel and at the same time underused. The problems associated with the use of the EIMS data base have been identified numerous times in the past by both Command EI managers and the Command Inspector General.

Discrepencies ranging from simple inaccuracies to incomplete data files are the significant problems which affect the user who attempts to interface the EIM System with the Hammell Method. These problems must be corrected through the attention of the managers, programmers and users of the EIM System in order for the information contained in the system's vast data base to be of any value to the workload assignment and scheduling programs.

The problems presently caused by the excessive amount of data manipulation mandated by the format requirements of the Hammell Method may be easily resolved once the models' programs are adapted and included in the AFCC Honeywell 6600 Computer. Data retrieval, manipulation, and reformatting may then be accomplished by simple program routines which read and rewrite portions of the EIMS data file into the format required by the assignment and scheduling models. Computerization of the data preparation steps will eliminate the labor intensive work presently required by the Hammell Method.

The required data which is not available within the EIM System may be accessed through other command programs or may be created as a new permanent data support base. This suggested data support base is a distance matrix consisting of virtually the same information shown in appendix B. Instead of requiring the program to refer to the appropriate information in the data matrix by line number, the program should require the computer to read the job location contained at position thirty-five in the EIMS data record file, and then search for the corresponding entry within the permanent distance matrix. The requirement to build an

extensive matrix is not anticipated at this time, nor at any time in the future. All EI work accomplished during fiscal year 1979 took place at one of 429 different locations; in fiscal year 1980 the locations numbered 420 (4:68). During these two years, many of the average 425 work locations remained the same which limits the magnitude of the distance matrix. The construction of a permanent distance matrix will alleviate the tedious workload experienced by the program user who is now required to format a new matrix each time the assignment model is changed.

Development of a reporting system similar to the present E-I Production Reporting System designed to project the status of team members and team chief availability for a specific time horizon, will eliminate the approximation method presently employed in both the assignment and the scheduling models. This proposed system will focus on the unit workcenter managers' best estimates of the availability of the direct labor personnel assigned to each shop. This will be accomplished by eliminating those personnel known to be unavailable for direct labor work from consideration. Engineering, Maintenance, and Installation productive labor; series 100 and 200 in the present Production Reporting System, will be used to indicate those personnel who are already productively employed and out of the mission available category. The remaining work force is projected as 300, 400, 500 and 600 series labor, which includes lag time, indirect production time, duty absences, and non-duty absences respectively. These four categories will also be removed from the available for labor category. That portion of the work force which

remains will be available for deployment. This number, along with the team chief availability status, will drive the scheduling and assignment models. It is realized that this system will not, except by chance, predict with perfect accuracy the actual availability picture during the time horizon of the model, but it will take into account those projected mission and non-mission temporary duty (TDY) absences, projected non-installations duties, leave, and training absences. The increase in accuracy allowed by this system will provide more realistic projections of availability for the schedule and assignment programs.

The Assignment Model

The value of the assignment model will be greatly increased by the use of the actual manpower availability figures obtained for each skill area from the projected manpower reporting system. Further changes to the assignment model include consideration of manpower availability within a particular skill area rather than across the entire unit, as the driving variable for particular skill assignments; the availability of a qualified team chief as a determinent for job assignment; and finally, the consideration of mission priority in the assignment algorithm as a means of preventing inappropriate accomplishment of low over high priority workload.

As shown in Chapter IV, the Hammell assignment method presently allows the program to assign workload of a specific skill requirement in excess of the unit's resource skill availability. A simplification of the assignment program, involving consideration of each skill area as a

separate assignment problem, will prevent this from occurring. For example, as before, Unit XYZ has three different skills assigned; A, B, and C; each possessing five hundred manhours of available labor. By considering each skill singularly, the program will correctly determine that there are only five hundred manhours available to support "A" type skill missions. Any "A" type skill mission, or combination of "A" type missions above five hundred manhours may not be assigned to Unit XYZ due to a lack of manpower. Multi-skill jobs, those which require the utilization of more than one skill type, may be handled by allowing the program to consider the job as two or more entirely separate missions, one for each required skill area. By this procedure, the program will delete each manhour assigned, thus insuring that the unit does not get overtasked.

The inclusion of the EI team chief availability as a resource variable, on a workcenter basis, will allow the program to resolve the problem of assigning workload to a unit which has the manpower to accomplish the mission but no team chief to lead the TDY. Use of this variable as a criteria for mission assignment will provide the added benefit of an audit trail for tracking those missions which were either unassigned or assigned to another unit as a result of insufficient team chief resources. This information will be valuable as justification for personnel and training actions required to upgrade the availability of team chiefs.

While the use of the distance between job locations and alternative EI resources as a truly representative determinant of travel cost was refuted in Chapter IV, the authors found that the cost of obtaining perfect, or near perfect cost comparison measures was not merited by the

increased cost effectiveness of the model. The amount of work, costs, and chance of error increase drastically with each additional variable entered into the cost estimation portion of the model. After numerous trials, it was determined that the assumptions made by Captain Hammell in this area allowed the most cost effective method of reducing travel costs. Comparison of alternative courses of action, to include commercial, government, and private transportation as a means of reducing travel costs, showed that there were no significant savings by using these alternatives. In addition, the use of distance between the job location and the EI resource as the driving factor for cost minimization, will insure that the recently introduced policy of creating a four hundred mile sanctuary around each EI unit will be accomplished (11). This distance is that which the EI Center has found to be the maximum the command can authorize for the use of privately owned vehicles as more advantageous to the government. This policy is desirable, according to Lt. Colonel Thomas Howes, Director of Installations, as it was strongly recommended in the Quality of Life survey.

Finally, the problems associated with assigning workload by the required operational date, rather than by mission importance, may be easily corrected through the utilization of the mission priority data base. By utilizing the stated mission priority to rank order the available jobs prior to running the assignment program, the program will have to consider all priority one jobs first, two jobs second, and so forth.

Restructuring the assignment program into a model which uses a general format and allows the introduction of both mission variables and resource variables as data input parameters rather than requiring computer code statement manipulation, will vastly increase the ease of operation of the system. By making the system easier to use, managers should be encouraged to experiment with different data to develop alternate assignment plans, thus providing them with a greater variety of information prior to the actual assignment process. The suggestion that the assignment model be changed from a program which considers assignments by unit, to one which works within each skill area, will reduce the computation time per run and reduce the need for extensive core memory space as is found with the present model. The program will no longer be required to manipulate five to six hundred jobs at one time, thus explaining the reduction in core space and computational time.

The Scheduling Model

Recommendations for the improvement of the scheduling model include those already presented for the assignment model. The same changes will enable increased utilization of a system which, in its present state, is already an excellent tool for unit-level workcenter managers.

Inclusion of the real world manpower data obtained from the suggested personnel availability reporting system, will improve the realism and utility of the scheduling system. The opportunity of the workcenter manager to insure that known non-available periods are included in the scheduling picture, will insure that the final product of the model more

closely portrays actuality. Personnel utilization should therefore be expected to show less variation than would have occurred under the approximation method.

Use of the variable referred to as team chief availability in the scheduling program will solve the problem of overtasking unit team chief personnel, insure maximum personnel utilization, and allow for the accounting of team chief personal leave, formal training, and certain in-house actions required before and after an installation mission.

In both these areas, the opportunity to manage workload and manpower availability becomes realistic. By obtaining a realistic schedule, and having the opportunity to vary workcenter inputs to the program which determines this schedule, the workcenter supervisor can readily see the effects of certain decisions. The workcenter supervisor can use this information to schedule leaves, TDYs, and other duty absences to the benefit of the mission and workcenter personnel.

Finally, the use of mission priorities to establish the relative importance of each mission will ensure that those missions which are higher in priority have a better chance of being completed prior to their required operational date.

Summary

While Captain Hammell's models provide an excellent application of quantitative methods and management science theory for the improved assignment and scheduling of EI workload, further development of his programs are required. Inclusion of certain real world data as either

mission or resource variables will insure that the programs provide realistic and usable information rather than simply serve as applications of quantitative techniques.

An analysis of data already contained in the EI Management System and the EI Production Reporting System shows that much of this information may be readily adapted as useful data for the models. Internal program routines may quickly structure this data in the required format, thus relieving the user of long and tedious labor.

The construction of a new data base, a permanent distance matrix, can be easily accomplished and maintained to further reduce a time consuming feature of the present Hammell Method.

The development of a new reporting system, or the inclusion of this system into the older Production Reporting System, will identify that labor which is not available for deployment and thus provide more accurate, up-to-date data for the models.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY

The objective of this thesis involved evaluation and improvement of the workload assignment and scheduling models developed by Capt. Scott A. Hammell. While Captain Hammell developed and verified a theoretical method, using quantitative means, to task electronics installations units with mission workload and then to schedule that workload in an optimum manner, actual field testing and validation, using real world data, was not attempted.

Conclusions

Four research questions were proposed, developed, and answered during the process of evaluating the Hammell assignment and scheduling models.

1. Is it possible to develop models to effectively assign and schedule EI workload?

The answer to this question was positive. The basic tasks facing Air Force Communications Command personnel are the identification of an optimal assignment of the command's resources to its assigned mission to meet the certain measurable criteria of cost, time, and mission completion.

The problem, therefore, takes on the aspects of assignment and scheduling of multi-skill resources to multi-skill jobs, a problem which has characteristics similar to the theories researched and developed in certain areas of management science. Once certain assumptions, criteria, and data requirements were identified and developed, model formulation was possible.

2. What are the major objectives of such assignment/scheduling models?

The objectives of these models are to efficiently and effectively utilize the limited resources of the Air Force Communications Command in the completion of its electronics installations unique mission. Incorporation of current command directives, policies, and desires ranging from cost minimization to improvement of quality of life aspects for the command's two thousand plus installer personnel entered the problem as factors to be considered in the development of those objectives which would drive the two programs.

3. What factors must be considered in these models?

As previously described, the factors which drive these models are those which directly relate to the command's objectives. Cost minimization resulted in decisions to minimize travel distance and to minimize the throughput time of the missions. Effective utilization of command resources translated into optimum mission scheduling to allow maximum utilization of available manpower. Mission completion was determined by successful completion of installations on or prior to the required operational date. Quality of life considerations resulted in the sub-

optimization of the effectiveness and efficiency objectives. However, command policy still considers allowing team members to have their privately owned vehicles on as many jobs as possible, maintaining minimum levels of personnel deployed TDY while still accomplishing the mission assigned to the command, and leveling the utilization of resources across all EI units within the command to be strong criteria.

Further factors to be considered by the models include refinements of those items which contribute to the success of the two models. Factors to be considered include realistic measurement of the resource availability within each unit and each skill area, accurate determination of team chief availability, and other refinements which will incorporate more real world data into the models.

4. How can EIMS be used with these models?

EIMS can be a major source of the data required to run the assignment and scheduling models. It was shown that the EI Management System now contains the mission location, priority, skill requirements, manpower requirements, required operational date, and earliest team start date. By constructing program routines to extract this data from the EIMS format and structure it in the format required by the two programs, the EIMS data base can become a useful and extremely important part of the Hammell Process.

Overall this thesis achieved its purpose of evaluating the Hammell assignment and scheduling models. By using real world information and attempting to use the models as an EI programmer would, the authors were able to both determine the feasibility of the models as they

are now constructed, and to develop methods to improve the models to provide more realistic and usable information to the user. The extensive electronics installations backgrounds of the authors were extremely helpful in determining those areas which were subject to improvement. As Captain Hammell noted in his work, there were several simplifying assumptions which had to be made during his research which moved the effort away from the real world environment and towards the conceptual world. We suggested the consideration of such real world aspects as team chief availability, variability of costs associated with different modes of travel, unit resource availability by skill, and mission priority. These suggestions, along with incorporation of suggested solutions to model problems identified in the validation process, should serve to improve the utility of the models. The success of this effort should serve to encourage others to develop and incorporate additional real world aspects in the models.

Recommendations for Further Study

It is recommended that additional research be conducted as a follow-on to this thesis. The models presented here, including the suggested improvements are in no way complete. Research developed from the point of view of the unit users of these models is required to identify further refinements. The authors recommend the assignment model as a tool to be used by the EI Center for allocation of the command mission assignments to units for accomplishment. The scheduling model, on the other hand, is a tool which is best utilized at the unit, either

at the workcenter level or at the branch level in workload control. By allowing the unit to further develop this model, the authors feel that still more possibilities for the further utilization of both the model and the Manpower Availability System may be realized.

Further refinement of both models must be accomplished by the professionals at the AFCC/ACD office. Restructuring the models into program code that will accept data changes by changing input parameters will be the most important portion of this work. An important effort is the refinement of the model output to provide the users with clearly understood information. There are many methods of redesigning the output to be more usable. Several suggestions include graphical representations of manpower utilization, listings of assignments, and chronological descriptions of workcenter schedules.

In case of tight TDY funding, a refinement of the assignment model which would insure that even the lowest priority job gets accomplished is recommended. The possibility exists that the system could identify all like skill jobs to be accomplished at a particular base each time the assignment model makes a mission allocation. EI managers may then make the manual decision of whether or not all or some of those jobs would be be accomplished. This decision would result in lower transportation costs and in lower total travel time but will also take manpower away from higher priority missions.

The possibility also exists that this method may be used to assign and schedule the Mobile Depot Level Maintenance mission also assigned to the Communications Command.

Many other areas of study may be recommended as follow-on efforts to this thesis. All additional work in this area has the potential to be useful in other areas of communications--electronics and should be carefully considered.

APPENDICES

APPENDIX A

LIST OF SAMPLE EI JOBS

This list of jobs is a sample of the job data used in Hammell's models.

JOB SITE	WIN[1]	M/H[2]	DUR[3]	ESD[4]	DUE[5]	Z	B	U	R	A	N	J	K	W	X	C	M	V	G	D	H
Wright-Patterson AFB	7054P0	640	129	283	412	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
Beale AFB	7155P0	100	30	296	326	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Richards-Gebaur AFB	7159P0	40	29	278	307	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Griffis AFB	9003Z9	15000	414	317	731	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ft Wayne MAP	5194P1	500	5	335	340	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
North Truro AFS	7018H1	600	304	334	638	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
McClellan AFB	7029J1	100	106	325	431	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Grissom AFB	7046L1	400	102	353	455	0	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Plattsburg AFB	0925A6	5332	151	301	452	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Vance AFB	0128T8	1613	71	339	410	0	4	2	0	0	0	0	0	0	0	0	3	0	0	0	0
Keesler AFB	0149A7	1092	18	286	304	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Moody AFB	0235A6	15470	198	350	548	0	2	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Ft Benning	0270R0	3000	166	284	450	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
England AFB	0855T1	90	2	351	353	0	2	1	0	0	0	0	0	0	0	0	0	1	0	0	0
Dauphin IS AFS	9501R9	400	9	303	312	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

1 WIN--work identification number
2 M/H--manhours
3 DUR--duration time
4 ESD--Estimated Start Date
5 DUE--Estimated Completion or Due Date

APPENDIX B

DISTANCE MATRIX

	Griffiss	Keesler	Kelly	McClellan	Norton
Beale AFB	2773	2350	1772	50	491
Brooks AFB	1815	616	14	1728	1736
Columbus AFB	1329	65	688	2333	1927
Griffiss AFB	1	1884	1819	2762	2692
Hancock FLD	40	1347	1780	2723	2658
Holloman AFB	2109	1851	1361	670	678
Keesler ABF	1383	1	623	2306	1883
Kelly AFB	1819	629	1	1728	1286
Lackland AFB	1823	627	1	1729	1237
Langley AFB	558	982	1598	2898	2620
McClellan AFB	2762	2306	1728	1	447
McDill AFB	1274	611	1236	2878	2422
Nellis AFB	2457	1803	1275	568	240
Norton AFB	2697	1883	1286	447	1
Plattsburg AFB	193	1290	1964	2948	2883

APPENDIX C

EIMS DATA RECORD FILE LISTING

DATA BASE DEFINITION FOR EPIC-EIMS

DATA FIELD NAME		STARTING POSITION	FIELD LENGTH
WIN	(Identification Number)	1	8
SEQ		1	4
TYPEWL		5	1
FY		6	1
AREA	(Area assigned)	7	1
AMD		8	1
PRGNR		9	8
PROID		17	9
CAT		17	1
CEMPAC		18	6
REQCMD		24	1
PROAMD		25	1
CCN		26	6
PC		32	1
HOST		33	2
MAJ		33	1
SUB		34	1
LOC	(Location)	35	4
FAC		39	4
CMDY	(Required Skills)	43	1
RODPOD	(Programmed Operational Date)	44	4

DATA BASE DEFINITION FOR EPIC-EIMS

DATA FIELD NAME	STARTING POSITION	FIELD LENGTH
RODIND	44	1
RODQFY	45	3
JCD	48	3
PRI (Job Priority)	51	4
ML	55	1
JOBRMK	56	3
APM	59	2
IPM	61	2
HPM	63	2
AGG	65	2
ERD	67	6
DMR	73	6
MIRD	79	6
DES	85	6
DLA	91	6
GROUP	97	1
BASENM (Base Name)	98	16
STATE	114	2
LCQTY	116	3
LCNOM	119	8
LCCOST	127	6

DATA BASE DEFINITION FOR EPIC-EIMS

DATA FIELD NAME	STARTING POSITION	FIELD LENGTH
SRD	133	3
DL01	136	7
DL02	143	7
DL03	150	7
DL04	157	7
DL05	164	7
DL06	171	7
DL07	178	7
DL08	185	7
DL09	192	7
DL10	199	7
DL11	206	7
DL12	213	7
DL13	220	7
DL14	227	7
DL15	234	7
DL16	241	7
DL17	248	7
DL18	255	7
DL19	262	7
DL20	269	7

DATA BASE DEFINITION FOR EPIC-EIMS

DATA FIELD NAME	STARTING POSITION	FIELD LENGTH
DL21	276	7
DL22	283	7
DL23	290	7
DL24	297	7
ESD	304	7
ESDDATE (Earliest Start Date)	304	6
ESDSTAT	310	1
SSA	311	7
SSSDATE	311	6
SSSSTAT	317	1
FSV	318	7
SCLDATE	318	6
SCLSTAT	324	1
FSC	325	7
SCRDATE	325	6
SCRSTAT	331	1
LMJ	332	7
LMSDATE	332	6
LMSSTAT	338	1
EFD	339	7
EFDDATE	339	6

DATA BASE DEFINITION FOR EPIC-EIMS

DATA FIELD NAME	STARTING POSITION	FIELD LENGTH
EFDSTAT	345	1
ECD	346	7
ECDDATE (Estimated Completion Date)	346	6
ESDSTAT	352	1
ENGBR	353	2
ENGSPT	355	5
ENGMTH	360	2
ENGRMK	362	3
M1	365	7
LMR	372	7
LMRDATE	372	6
LMRSTAT	378	1
M3	379	7
M4	386	7
MSD	393	7
MSDATE	393	6
MSDSTAT	399	1
M6	400	7
MAD	407	7
MADDATE	407	6
MADSTAT	413	1

DATA BASE DEFINITION FOR EPIC-EIMS

DATA FIELD NAME	STARTING POSITION	FIELD LENGTH
MM	419	2
MATMTH	421	2
MATRMK	423	3
EIR	426	7
EIRDATE	426	6
EIRSTAT	432	1
WR	433	7
WRDATE	433	6
WRSTAT	439	1
ASC	440	7
ASCDATE	440	6
ASCSTAT	446	1
TSR	447	
TSRDATE	447	6
TSRSTAT	453	1
PSS	454	7
PSSDATE	454	6
PSSSTAT	460	1
PSC	461	7
PSCDATE	461	6
PSCSTAT	467	1

DATA BASE DEFINITION FOR EPIC-EIMS

DATA FIELD NAME	STARTING POSITION	FIELD LENGTH
TSD	468	7
TSDDATE (Team Start Date)	468	6
TSDSTAT	474	1
TCD	475	7
TCDDATE	475	6
TCDSTAT	481	1
MIMTH	482	2
MIRMK	484	3
MIRESP	487	6
MISPT	493	6
PIP	499	7
PIPDATE	499	6
PIPSTAT	505	1
PIPBR	506	2
PIPRMK	508	3
TOA	511	7
TOADATE	511	6
TOASTAT	517	1
CDD	518	12
CDDDATE	518	6
CDDSTAT	524	1

DATA BASE DEFINITION FOR EPIC-EIMS

DATA FIELD NAME		STARTING POSITION	FIELD LENGTH
SOW		525	5
RELSCH		530	2
RELENG		532	2
ECRA	(Engineering Changes)	534	4
ENGNME		538	12
ENGTEL		550	7
TEAM		557	9
MCP		566	10
TITLE		630	19
NARR	(Job Description)	649	41
ENGEST		690	6
ENGCUR		696	6
ENGTOT		702	6
ENGREM		708	6
MIEST		714	6
MICUR		720	6
MITOT		726	6
MIREM		732	6
ORGROD		738	4
HIAMOS		742	2
EXCMOS		744	2

DATA BASE DEFINITION FOR EPIC-EIMS

DATA FIELD NAME	STARTING POSITION	FIELD LENGTH
ORGMIEST	746	6
ORGTCD	752	7
ORGENGEST	759	6
ORGECD	765	7
ORGERD	772	6
ORGDMR	778	6
ORGMIRD	784	6
CMPDELCD	790	1
CMPDELYRMO	791	4
ORGASC	795	4
PROGAPRVDT	799	6
PPMOS	805	2
ZMIMOS	807	2
RCDTYPE	809	1

APPENDIX D

ASSIGNMENT COMPUTER PROGRAMS

CONTROL CARDS FOR LP6000 SOFTWARE PACKAGE

```
0010##S,J ;,8,16
0020$;IDENT;WP0354,81A120,CAPT NELSON,AFIT/LSA(GLM81J)
0025$;USERID;81A120$IL66
0030$;PROGRAM;RLHS,NDUMP
0040$;LIMITS;15,45K,,3K
0050$;PRMFL;H*,R,R,AF.LIB/LP.PAC
0060$;FILE;A1,X1R,10R
0070$;FILE;A2,X2R,10R
0080$;FILE;A3,X3R,10R
0090$;FILE;A4,X4R,10R
0100$;FILE;A5,X5R,10R
0110$;REMOTE;SO
0120$;DATA;I*
0130;PREPRO
0140;TITLE;***** WORKLOAD ASSIGNMENT *****
0150;CONVERT;SOURCE=TDATA/IN,IDENT=PROB
0160;SETUP;SOURCE=PROB
0170;SET;OBJ=MILES
0180;SET;RHS=AVMHRS
0190;INTEGER
0200;OUTPUT
0210;ENDLP
0220;EXECUTE
0230$;DATA;IN
0240$;SELECTA;81A120/ASGNDATA
0250$;ENDJOB
```

```
C ############################################################
C  PROGRAM "ASGNTEST" BUILDS THE LP6000 INPUT CARD
C     STREAM FOR A TEST ASSIGNMENT PROBLEM OF
C        FEWER THAN THE 196 E-I JOBS POSSIBLE.
C ############################################################
C
      CHARACTER LOC*6(196),WIN*6(196),UNIT*6(5)
      DIMENSION RQMHRS(196),AVMHRS(196),DIST(5,196),C(5,196)
     &,KK(196,16),ESD(196),DUR(196),DUE(196)
      INTEGER MILESET(196),L(135)
C
      DATA (UNIT(I),I=1,5)/"0485M4","1839C7","1827C6",
     &"1849M8","1835C9"/
C
      DATA (AVMHRS(I),I=1,5)/30160.0,35025.0,17756.0,
     &38115.0,18427.0/
C
      DATA (L(LL),LL=1,135)/1,2,3,4,5,6,8,9,11,12,13,15,16,18,
     &20,21,23,24,26,27,28,31,32,35,36,38,39,42,43,45,47,49,
     &50,52,54,55,56,57,59,60,61,62,63,64,65,68,69,72,73,75,
     &76,78,79,80,81,82,83,84,85,86,87,89,90,92,93,95,96,97,99,
     &101,102,104,105,107,109,110,111,113,115,116,117,119,120,121,
     &122,124,125,126,128,130,131,135,136,137,138,140,141,142,143,145,
     &146,148,149,151,152,154,156,157,159,160,161,163,167,168,
     &169,172,173,175,176,179,180,182,183,184,185,187,188,189,
     &190,191,192,193,194,195,196/
C
      M=5
      N=196
      NN=135
      SKL=16
C
      READ(10,300)LOC(J),WIN(J),RQMHRS(J),MILESET(J),
     &DUR(J),ESD(J),DUE(J),(KK(J,K),K=1,SKL)
      DO 10 J=1,196
   10 CONTINUE
  300 FORMAT(V)
      PRINT,'LOC=',LOC(196)
C
      DO 20 II=1,87
      READ(10,400,END=30)(DIST(I,II),I=1,5)
   20 CONTINUE
  400 FORMAT(V)
C
      WRITE(9,999)
  999 FORMAT(4HFILE,3X,5HTDATA)
C
      DO 1111 I=1,M
      DO 1111 LL=1,NN
      JJ=L(LL)
      WRITE(9,1000)(LOC(JJ),WIN(JJ),UNIT(I))
 1000 FORMAT(1HS,6X,A6,2(1H:,A6),1X,13H(INTEGER=0,1))
 1111 CONTINUE
C
```

```
      WRITE(9,2000)
 2000 FORMAT(1HL,6X,5HMILES,3X,3H(F))
C
      WRITE(9,3000)(UNIT(I),I=1,M)
 3000 FORMAT(1HL,6X,A6,2X,3H(P))
C
      DO 4444 LL=1,NN
      JJ=L(LL)
      WRITE(9,4000)(LOC(JJ),WIN(JJ))
 4000 FORMAT(1HL,6X,A6,1H:,A6,2X,3H(Z))
 4444 CONTINUE
C
      DO 5555 I=1,M
      DO 5555 LL=1,NN
      JJ=L(LL)
      K=MILESET(JJ)
      C(I,K)=DIST(I,K)
 4100 IF(KK(JJ,1))4110,4110,4101
 4101 C(3,K)=999999
      C(4,K)=999999
 4110 IF(KK(JJ,7))4120,4120,4111
 4111 C(4,K)=999999
 4120 IF(KK(JJ,8))4130,4130,4121
 4121 C(5,K)=999999
 4130 IF(KK(JJ,10))4140,4140,4131
 4131 C(3,K)=999999
 4140 IF(KK(JJ,11))4150,4150,4141
 4141 C(5,K)=999999
 4150 IF(KK(JJ,12))4160,4160,4151
 4151 C(1,K)=999999
      C(2,K)=999999
      C(5,K)=999999
 4160 IF(KK(JJ,13))4170,4170,4161
 4161 C(1,K)=999999
      C(5,K)=999999
 4170 IF(KK(JJ,14))4180,4180,4171
 4171 C(1,K)=999999
      C(3,K)=999999
      C(4,K)=999999
      C(5,K)=999999
 4180 IF(KK(JJ,15))4190,4190,4181
 4181 C(1,K)=999999
      C(2,K)=999999
      C(3,K)=999999
      C(5,K)=999999
 4190 IF(KK(JJ,16))4200,4200,4191
 4191 C(1,K)=999999
      C(3,K)=999999
      C(4,K)=999999
      C(5,K)=999999
 4200 WRITE(9,5000)(LOC(JJ),WIN(JJ),UNIT(I),C(I,K))
 5000 FORMAT(1HA,6X,7HMILES ,,A6,2(1H:,A6),1H=,F8.0)
 5555 CONTINUE
C
```

```
      DO 6666 I=1,M
      DO 6666 LL=1,NN
      JJ=L(LL)
      WRITE(9,6000)(UNIT(I),LOC(JJ),WIN(JJ),UNIT(I),RQMHRS(JJ))
 6000 FORMAT(1HA,6X,A6,1H,,A6,2(1H:,A6),1H=,F8.0)
 6666 CONTINUE
C
      DO 7777 LL=1,NN
      DO 7777 I=1,M
      JJ=L(LL)
      WRITE(9,7000)(LOC(JJ),WIN(JJ),LOC(JJ),WIN(JJ),UNIT(I))
 7000 FORMAT(1HA,6X,A6,1H:,A6,1H,,A6,2(1H:,A6),4H= 1.)
 7777 CONTINUE
C
      WRITE(9,8000)(UNIT(I),AVMHRS(I),I=1,M)
 8000 FORMAT(1HB,6X,A6,8H,AVMHRS=,F9.0)
C
      DO 9999 LL=1,NN
      JJ=L(LL)
      WRITE(9,9000)(LOC(JJ),WIN(JJ))
 9000 FORMAT(1HB,6X,A6,1H:,A6,11H,AVMHRS= 1.)
 9999 CONTINUE
C
      WRITE(9,9100)
 9100 FORMAT(6HEND***)
      GO TO 40
   30 PRINT,'END OF FILE II=',II,(DIST(I,II),I=1,5)
   40 CONTINUE
C
      STOP
      END
```

SELECTED BIBLIOGRAPHY

A. REFERENCES CITED

1. Air Force Communications Command Regulation 25-320. Engineering-Installation Work Measurement System. Richards-Gebaur AFB MO: April 1976.

2. Air Force Communications Command Regulation 100-103. Engineering and Installation Production Reporting System. Scott AFB IL: July 1980.

3. Air Force Communications Service TAB 35123. EIMS Software. Scott AFB IL: 1979.

4. "Air Force Communications Command," Air Force Magazine. May 1981.

5. Anderson, David R., Dennis J. Sweeney, and Thomas A. Williams. An Introduction to Management Science, Quantitative Approaches to Decision Making. St Paul MN: West Publishing Company, 1976.

6. Chase, Richard B., and Nicholas J. Aquilano. Production and Operations Management. Rev. ed. Homewood IL: Richard D. Irwin, Inc., 1977.

7. Conway, R. W. An Experimental Investigation of Priority Assignment in a Job Shop. Memorandum, RM-3789-PR. Santa Monica CA: The Rand Corporation, February, 1964.

8. Cox, Colonel Gene A., USAF. Deputy Chief of Staff for Engineering, Programs and Acquistions, HQ AFCC/EP, Scott AFB IL. Letter, subject: AFCC Realignment Study, to HQ AFCC/XP, 19 March 1979 with Attachment 1, subject: Concept of EI Workloading, 14 March 1980.

9. Davis, Edward W. "An Exact Algorithm for the Multiple Constrained Resource Project Scheduling Problem." Unpublished dissertation, Yale University, New Haven CT: 1968.

10. Hammell, Captain Scott A., USAF. "An Approach to Workload Assignment and Scheduling of Engineering and Installation Activities for Air Force Communications Command (AFCC)." Unpublished master's thesis. LSSR 85-80, School of Systems and Logistics, Air Force Institute of Technology, Wright-Patterson AFB OH: September 1980.

11. Howes, Lieutenant Colonel Thomas R., USAF. Deputy for Installations, Engineering and Installations Center (AFCC), Oklahoma City AFS OK: Telephone interview. April 1981.

12. Nauseef, Lieutenant Colonel John, USAF, Squadron Leader A. G. Tahir, Pakistan Air Force, and Captain Ted I. Zindenberg, USAF. "The Identification of Performance Indicators for the Engineering and Installation of Ground CEM Systems." Unpublished master's thesis. LSSR 17-79B, School of Systems and Logistics, Air Force Institute of Technology, Wright-Patterson AFB OH: September 1979. ADA 077027.

13. Pritsker, Alan B., and Lawrence J. Watters. A Zero-One Programming Approach to Scheduling with Limited Resources. Memorandum, RM-5561-PR. Santa Monica CA: The Rand Corporation, January 1968. AD 664551.

14. Salvador, Michael S. "Scheduling and Sequencing," in Joseph J. Moder and Salah E. Elmaghraby, eds., Handbook of Operations Research, Vol. 2. New York: Van Nostrand Reinhold Co., 1978.

15. Stewart, Lieutenant Colonel Joseph T., USAF. Deputy Chief of Staff for Engineering and Installations, Northern Communications Area (AFCC), Griffiss AFB NY: Telephone interview. September 1980.

16. ________. Personal interview. November 1980.

17. U.S. Department of the Air Force. Official Table of Distances. AFR 177-135. Washington: Government Printing Office, January 1980.

B. RELATED SOURCES

Colburn, Major Gene, USAF. Director of Mission Support, Engineering and Installations Center (AFCC), Oklahoma City AFS OK: Letter, Subject: AFCC Direct Labor Assignments. 21 April 1981.

Honeywell Series 600/6000 Software. Introduction to Linear Programming System. Reference manual. BP50. Wellesley Hills MA: Honeywell Information Systems, Inc., April 1972.

_______. LP6000 System Mixed Integer Program. Reference manual. DA88. Wellesley Hills MA: Honeywell Information Systems, Inc., April 1972.

_______. LP6000 System Input File Preparation. Reference manual. BQ01. Wellesley Hills MA: Honeywell Information Systems, Inc., April 1972.

Keen, Peter G. W., and Michael S. Scott Morton. Decision Support Systems, An Organizational Perspective. Reading MA: Addison-Wesley Publishing Company. 1978.

Schoderbek, Charles G., and Peter P. Schoderbek, and Asterios G. Defalas. Management Systems, Conceptual Considerations. Dallas TX: Business Publications, Inc., Rev. ed. 1980.

Shannon, Robert E. Systems Simulation, The Art and Science. Englewood Cliffs NJ: Prentice-Hall, Inc. 1975.

Snyder, Major Robert, Northern Communications Area (AFCC), Directorate of Plans and Programs. Briefing, Subject: AFCC Reorganization. 21 November 1980.

BIOGRAPHICAL SKETCHES

Captain Raymond J. Brylski was born in New York City and grew up in the Long Island town of Mastic Beach, New York. He received a Bachelor of Science in Vocational Industrial Education from Virginia Polytechnic Institute in 1972 and a Master of Arts in Business Administration from Central Michigan University in 1978. A graduate of the AFROTC program at VPI, he was commissioned at Eglin AFB, FL in July 1972. Captain Brylski has served as team commander, project director, and electronics chief with the 485th Electronics Installation Squadron, Griffiss AFB, NY; chief of maintenance at the 2016th Communications Squadron, Dover AFB, DE; and Commander, 1983rd Communications Squadron, Thule AB, Greenland. His next assignment is to Langley AFB, VA, as a member of the Air Force Communications Command Inspector General team, attached to Headquarters Tactical Air Command.

Captain Louise M. Nelson was born and grew up in Marion, Ohio. A graduate of Ohio State University in 1973 with a Bachelor of Arts degree in Social Science, Captain Nelson received her commission from the Air Force Officer's Training School, Lackland AFB, Texas, in December 1973. After attending the Communications-Electronics (C-E) Maintenance Officer course at Keesler AFB, Mississippi, she served as the Chief of Maintenance, 2103rd Communications Squadron, Ellington AFB, Texas. In October 1976 Captain Nelson was assigned to the Air Force Data Systems Design Center, Gunter AFS, Alabama, as a C-E Functional Analyst. Prior to her assignment to AFIT, she served as the Chief, Electronics Division, 2046th Communications Installation Group, Wright-Patterson, Ohio. After graduation she will be assigned to the Electronics System Division (AFSC), Hanscom AFB, Massachusetts.

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